6.0 Block Valve Effectiveness

Once a pipeline rupture develops, the actual spill volume is comprised of four components:

- discharge through the rupture until it is detected and the shipping pumps are shut-off (this spill volume component will be called *continued pumping*),
- pipeline fluid decompression through the rupture until the block valves are closed,
- continued fluid decompression between adjacent block valves after valve closure, and
- the pipeline drain down.

In this section, we will examine each of these items and how block valves affect the resulting spill volume. The leak data obtained from the pipeline operators in this study will then be examined. Using this data, a cost/benefit analysis for adding additional block valves will be presented. Finally, the results of other studies regarding remotely and automatically operated block valves will be reviewed.

6.1 Continued Pumping

Once a leak develops, it must be detected before corrective action can be taken. The time required for a leak to be detected generally depends on the spill rate, leak location, and the sophistication of the leak detection system, if any, installed.

The total time of continued pumping is comprised of two components. First, the leak must be identified. Second, the pipeline operator must confirm that the alarm or leak report was indeed a leak, initiate pump shut-down, and then wait for the pumps to actually stop. This sequence can vary from only a few minutes for systems with remotely operated pumps, to hours for unmanned, manually operated equipment in remote areas. Some of the factors which affect the second component include:

- type of operating equipment controls (automatically, remotely or manually operated),
- distance of personnel from manually operated shut-down equipment at time of leak discovery,
- work hours of personnel at manually operated facilities (e.g. response times for facilities manned 24 hours per day, 7 days a week are not generally affected by leaks late at night or on weekends),

- communications network, etc.

The time required to identify that a leak exists also varies considerably. For pipelines with modern SCADA systems, which include leak detection software, leaks are often initially detected when alarms sound in the central monitoring facility. Experience has shown that these systems often alarm within only a couple of minutes of a relatively large rupture. There are presently three basic types of leak detection software in general use:

- over/short accounting,
- volumetric balance, with or without line pack corrections, and
- pressure profiling.

Over/short accounting is the traditional method of metering all volumes which enter and leave a pipeline system. The cumulative volumes entering and leaving the system are then compared. This method is useful for detecting small leaks, but requires relatively long time intervals for the cumulative volume difference to become significant enough to be identified. Naturally, the length of time required to identify a leak depends on the actual leak rate. The larger the leak, the shorter the time interval required to detect it and the higher the confidence level that a leak actually exists.

Volumetric balance compares the flow rates of the fluid entering and leaving a pipeline system. Most of these programs include volumetric corrections for pressure and temperature. The performance of these systems vary considerably between different pipelines. They work best on pipelines with relatively constant operating parameters (e.g. flow rate, pressure, temperature, etc.). In some applications (e.g. slack lines) they may have very poor performance. Volumetric balance leak detection systems are generally considered useful in detecting moderate size leaks in a relatively short amount of time.

Pressure profile systems generally have a faster response than the over/short accounting or volumetric balance systems. However, until recently, these systems have only been useful in quickly identifying large spills. When such a spill occurs, a pressure wave travels through the line. The fluctuation is then detected by the leak detection software. The sophisticated software compares the actual fluctuation to anticipated fluctuations which may result from operating condition changes. The system will trigger an alarm if there is a significant discrepancy between the anticipated and actual situation.

For pipelines without leak detection systems, and frequently for relatively slow, small leaks from pipelines with leak detection systems, leaks are often discovered after fluid pools on the earth's surface. Depending on the location, it may be discovered by the public, by the pipeline operator during his line patrol, etc. The time required may range from minutes, up to several days for these leaks to be identified.

For a given leak size, the spill volume due to continued pumping (V_p) can be calculated using the following equation:

$$V_p = Q * (T_1 + T_2)$$

where: V_p = spill volume caused by continued pumping (barrels)
Q = leak size flow rate (barrels per minute)
T_1 = time required to detect leak (minutes)
T_2 = time required to shut-off pumps (minutes)

6.2 Fluid Decompression

Although we normally consider fluids incompressible, petroleum fluid volumes at atmospheric pressure for pipelines operated at high pressure are much greater than one might expect. Once a leak develops, the fluid volume increases as pressure is released through the rupture. This occurs in two steps. First, between pump shut-down and block valve closure, a portion of the entire line pack is spilled. For short block valve closure time intervals, this volume can be estimated as follows:

$$V_{d1} = T_3 * Q_L$$

where: V_{d1} = partial decompression spill volume (barrels)
Q_L = leak flow rate (barrels per minute)
T_3 = time interval between pump shut-down and valve closure (minutes)

For extremely long block valve closure intervals, the decompression spill volume approaches the total *line pack*, or the difference in pipeline volume between ambient and actual operating conditions. For intermediate valve closure times, the decompression spill volume is rather difficult to calculate. However, a reasonable approximation could be made by interpolation.

The second component occurs from the remaining decompression between the closed block valves on either side of the rupture. This value can be estimated as follows:

$$V_{d2} = L_1/L_2 * (P - V_{d1})$$

where: V_{d2} = partial decompression spill volume (barrels)
L_1 = distance between adjacent block valves (miles)
L_2 = total pipeline length (miles)
P = line pack (barrels)

The total fluid decompression spill volume can then be determined by adding the sum of the spill volumes before and after valve closure ($V_{d1} + V_{d2}$).

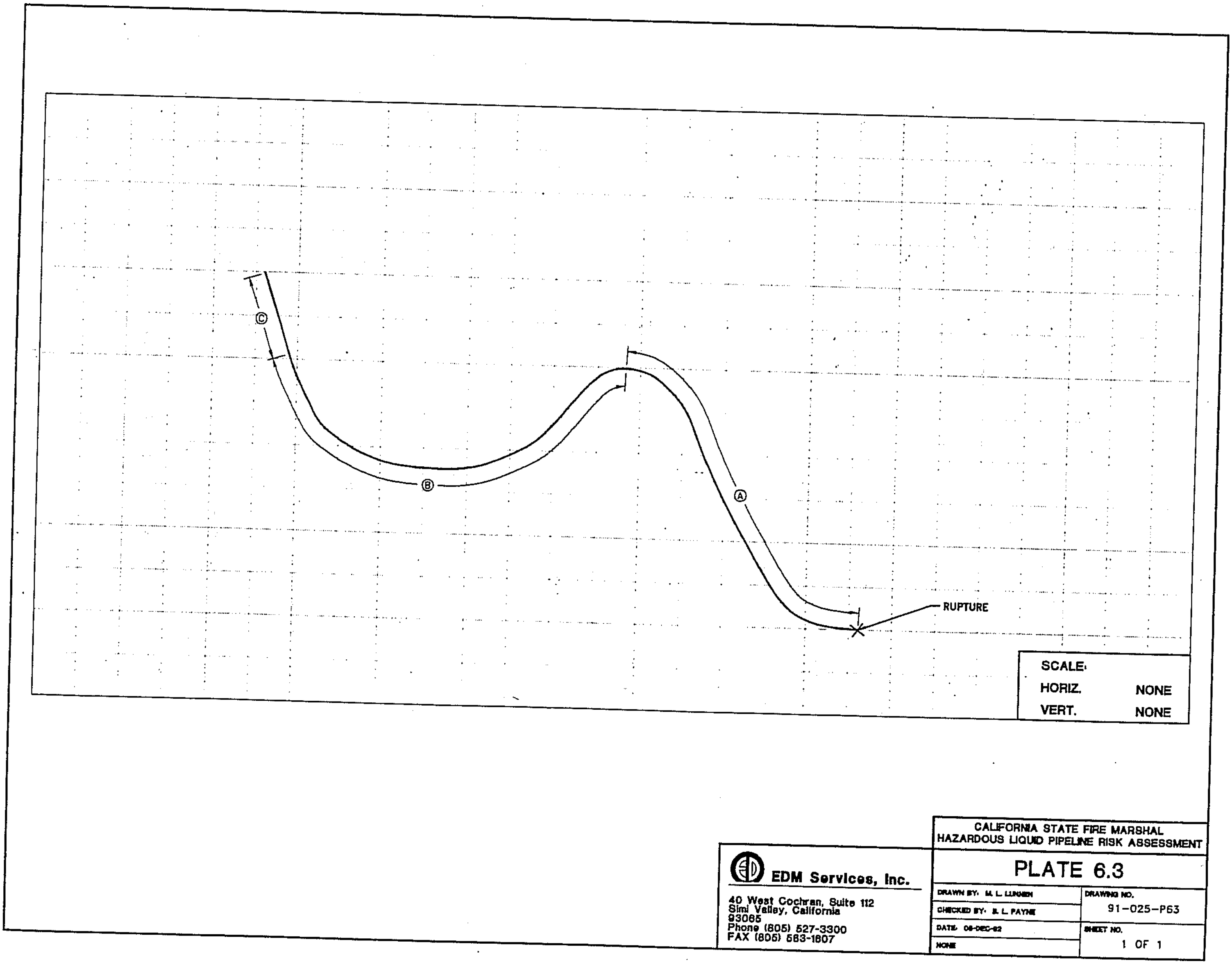
6.3 Drain Down

The final spill volume component, drain down, is the most difficult to predict. It is directly related to the leak location and the pipeline profile. Often this volume varies considerably for various locations along a given line. For example, a rupture at the highest point of a line would not result in any drain down volume. On the other hand, a leak in a low section could result in a significant drain down; in some cases it could include the total volume of line between adjacent block valves on either side of the rupture. As we will see in Section 6.5, in most instances, the actual drain down spill volume is only a small fraction of the total distance between adjacent block valves.

The rate at which fluid will drain from a leak is difficult to predict. It depends, among other things, on the size of the leak, the pipeline profile, the fluid viscosity, etc. Often, the fact that the pipeline section is a *closed* system is overlooked. In order for fluid to drain from the line, air must enter to displace the fluid. This is somewhat similar to turning a full soda pop can up-side-down; the soda would spill relatively slowly as air *bubbles* into the can to displace it. If however, a hole is made in the top of the can to allow air to enter, soda will flow readily, since air will be available to displace it.

In hilly or mountainous terrain, determining the length of line which will drain from a rupture is not straightforward. Consider the example shown on Plate 6.3. The length "A", from the rupture to the crest of the first hill, will drain as air *bubbles* into the line as previously discussed. However, air will not move past the hill crest, since the pressure in the line beyond the crest is greater than atmospheric. The length "B" will not drain from the line; it will remain pocketed in the low section. The amount of segment "C" which will drain is difficult to determine. Since air can't migrate into the section to displace the fluid, the fluid will pull a vacuum on the upper section of pipe, equal to the weight of the vertical column of fluid. Depending on the fluid, various volumes of light hydrocarbons will *gas off*. As this occurs, some percentage of the length "C" will drain from the rupture.

Plate 6.3


C
B
A
RUPTURE
SCALE:
HORIZ. NONE
VERT. NONE
EDM Services, Inc.
40 West Cochran, Suite 112
Simi Valley, California
93065
Phone (805) 527-3300
FAX (805) 583-1607
CALIFORNIA STATE FIRE MARSHAL
HAZARDOUS LIQUID PIPELINE RISK ASSESSMENT
PLATE 6.3
DRAWN BY:
CHECKED BY:
DATE:
NONE
DRAWING NO.
91-025-P63
SHEET NO.
1 OF 1

This situation is significantly different than for gas pipelines, where the entire line segment contents are released into the atmosphere. As shown in the example, the terrain frequently creates natural check valves on liquid lines which prevent large percentages of the total pipeline volume from being spilled. This principle makes direct comparison between block valve effectiveness on liquid and gas lines impossible.

6.4 Spill Components Affected By Block Valves

The effectiveness of block valves on hazardous liquid pipeline spill volumes is directly related to:

- the leak's physical location in relationship to the valve,
- the pipeline profile, and
- the time required to close the valve once a leak has been identified.

For example, a block valve would be very effective in minimizing the drain down portion of a spill caused by a leak immediately downslope from it, assuming it could be readily closed. On the other hand, in many cases it would have no affect on the drain down portion of a spill immediately upslope, even if it could be immediately closed.

In addition to potentially reducing drain down spill volumes, block valves which can be closed immediately after pump shut-down may also slightly reduce the fluid decompression spill volumes. (See also Section 6.2.).

Block valves do not reduce spill volumes caused by continued pumping. This spill volume can only be reduced by rapid leak identification and pump shut-down. Modern SCADA systems, utilizing leak detection software, are effective in reducing this spill volume component.

In short, for hazardous liquid pipelines:

- Block valves are only effective in significantly reducing the drain down component of a spill. In many instances, the terrain reduces the actual drain down volume to only a fraction of the distance between adjacent block valves.

- Block valves are not effective in significantly reducing the total spill volume unless the leak can be quickly identified. Installing additional block valves on a line without a leak detection system (either continuous visual monitoring or modern SCADA system with leak detection) is somewhat like putting the cart before the horse.

- Finally, in many cases, block valves effectiveness decreases as the length of time required to close them increases.

6.5 Block Valve Effectiveness Data

Some earlier studies have assumed that block valve effectiveness is directly related to the length of line between adjacent valves. Following this logic, it has been assumed that by reducing the distance between block valves by say a factor of two, the resulting spill volume and subsequent damage would be halved. While this may be partially true for gas lines, it is certainly not the case for most hazardous liquid pipelines, as we shall see. Even if the spill volume could be reduced in direct proportion to block valve spacing, the resulting damage would not be proportionally reduced; in most cases, the first barrels spilled result in much more costly damage, injury and loss of life than subsequent barrels spilled.

During data collection, the EDM Services' technicians attempted to gather information which would facilitate a block valve effectiveness analysis. To this end, the spill volume and the distance to the nearest block valve on each side of each leak were collected. In addition, data was collected from each pipeline operator regarding the total pipeline lengths and number of block valves installed on each of their regulated hazardous liquid pipelines. This data is summarized below:

Number of Pipe Sections With Block Valve Data	552 Pipelines
Average Block Valve Spacing	3.12 Miles
Median Block Valve Spacing	1.39 Miles
Total Number of Intermediate Block Valves Installed	1,909 Valves
Total Length of Pipelines With Block Valve Data	7,679 Miles

This valve spacing data has also been depicted graphically in Table 6-5A. The large variation between the average and median block valve spacings indicate that the few pipelines with high average block valve spacings affected the average value considerably. This fact is also shown by the shape of the curve on Table 6-5A. The following values are worth noting:

- 25% of the pipeline systems had an average block valve spacing of 0.52 miles or less.
- 50% of the pipeline systems had an average block valve spacing of 1.39 miles or less.
- 75% of the pipeline systems had an average block valve spacing of 3.00 miles or less.
- 90% of the pipeline systems had an average block valve spacing of 6.36 miles or less.
- Only 22 pipelines (4% of the total) had average block valve spacings of 10.00 miles or more. Only 15 of these pipelines were over 20 miles long.
- The longest average block valve spacing on an individual pipeline was 56 miles.

Similar data was also collected for each of the leaks included in the study for which such information was available. These data included the distance to the nearest block valve on either side of the rupture, the spill size, and various other specific data. They are summarized below:

Number of Leaks With Adjacent Block Valve Distance Data	454 Leaks
Average Total Distance Between Adjacent Block Valves On Each Side of Leak	6.13 Miles
Median Total Distance Between Adjacent Block Valves On Each Side of Leak	3.4 Miles
Average Spill Size	419 Barrels
Median Spill Size	5 Barrels

Table 6-5B presents the distribution of the total distance between the adjacent block valves on either side of each leak. These lengths were then added to determine the total length of line which could drain down through the rupture. (This length will also be referred to as the *maximum potential drain down length.*) As noted above, we were able to compile this data for 454 (88%) of the leaks included in this study. Various values along the distribution curve are presented below:

- 25% of the leaks had a maximum potential drain down length of 1.4 miles or less.
- 50% of the leaks had a maximum potential drain down length of 3.4 miles or less.
- 75% of the leaks had a maximum potential drain down length of 8.1 miles or less.
- 90% of the leaks had a maximum potential drain down length of 16.6 miles or less.
- 95% of the leaks had a maximum potential drain down length of 18 miles or less.
- The longest maximum potential drain down length for an individual leak was 71 miles. (It's interesting to note that the leak which occurred on this segment resulted in only a one barrel spill.)

Table 6-5C presents the distribution of spill sizes for the 454 leaks with adjacent block valve distance information. As indicated, the vast majority of the leaks had very small spill volumes. However, a few relatively large spills resulted in an average spill size much higher than the median, 419 versus 5 barrels. The shape of this curve is virtually identical to the spill size distribution curve presented in Table 4-22 for all leaks included in the study.

As discussed in the prior subsections, block valves are only effective in controlling a portion of the total spill volume. One method of evaluating block valve effectiveness in controlling spill volumes is to examine the percentage of the maximum potential drain down which was actually spilled. This was done for each of the 454 incidents with adjacent block valve distance data as follows:

Table 6–5A
Average Valve Spacing Distribution
All Pipelines Included In Study

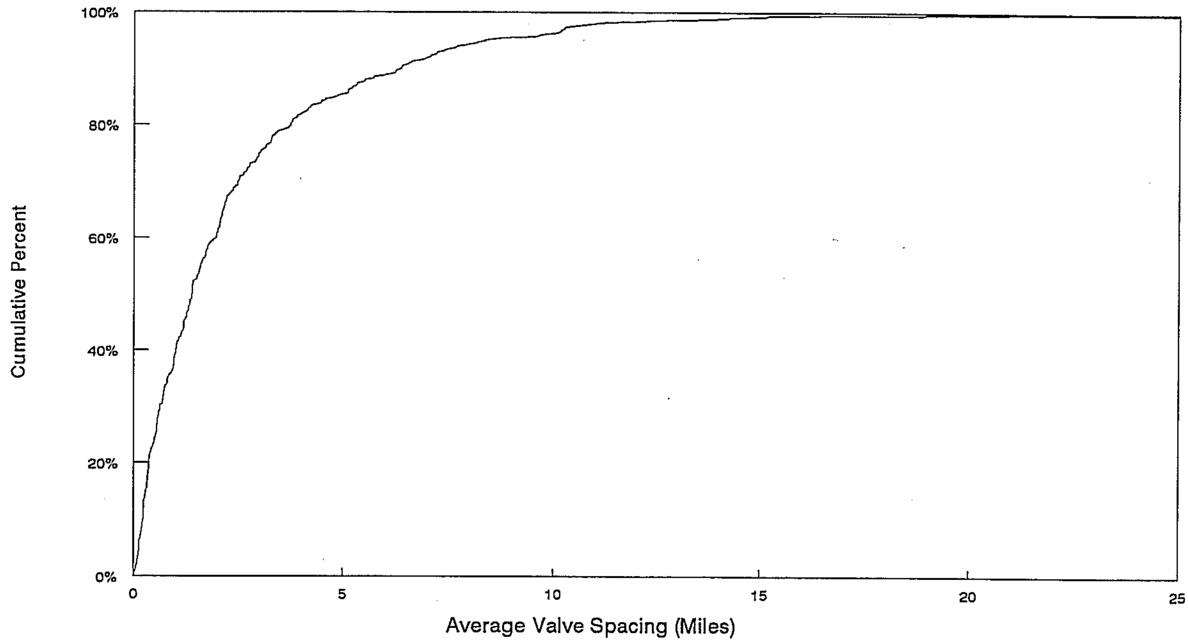
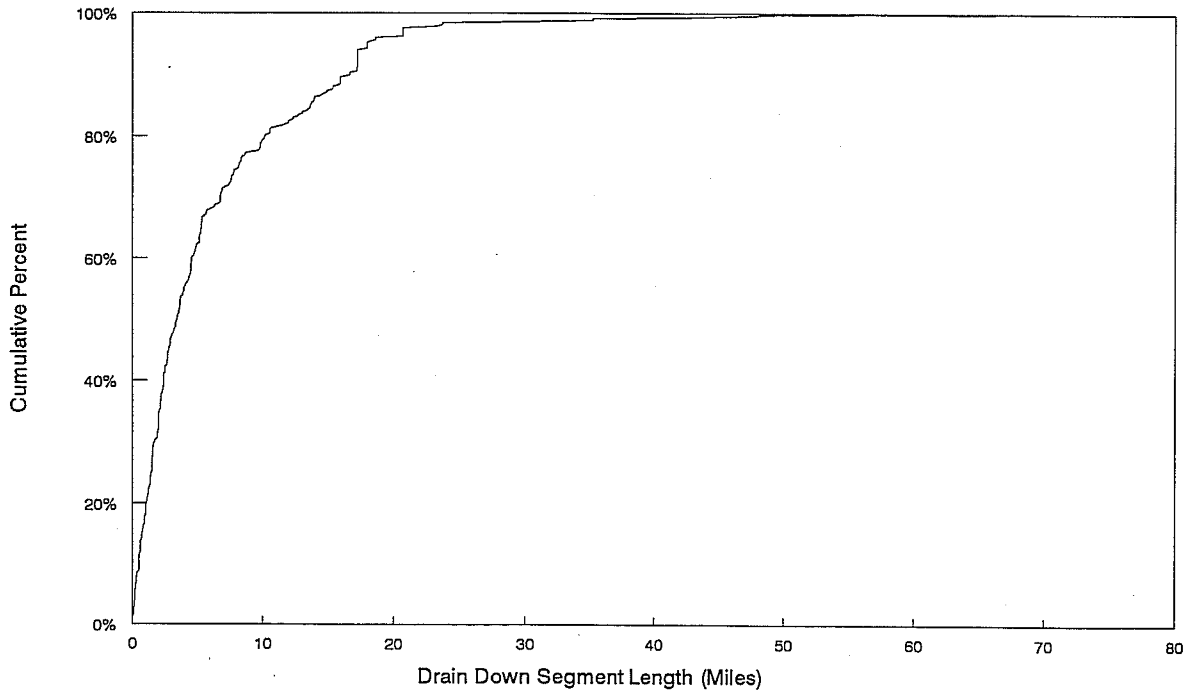


Table 6–5B
Potential Drain Down Length Distribution
For Leaks With Adjacent Valve Spacing Distances



- The length of pipe with an internal volume equivalent to the spill volume was calculated for each leak using the following equation:

  $L_{Leak} = (0.15315 * V_{Spill}) \div \{3.1416 * (O.D./2 - w.t.)^2\}$

  where: L_{Leak} = Equivalent Pipe Length (miles)
  V_{Spill} = Spill Volume (barrels)
  O.D. = Outside Pipe Diameter (inches)
  w.t. = Pipe Wall Thickness (inches)

- The maximum potential drain down length was determined by adding the distance to the nearest adjacent block valves.

  $L_{Drain} = L_{V1} + L_{V2}$

  where: L_{Drain} = Maximum Potential Drain Down Length (miles)
  L_{V1} = Distance to Nearest Upstream Block Valve (miles)
  L_{V2} = Distance to Nearest Downstream Block Valve (miles)

- The percentage of the maximum potential drain down which was actually spilled was then determined for each leak by simple division as follows:

  $\%_{Drain} = L_{Leak} \div L_{Drain} * 100\%$

  where: $\%_{Drain}$ = Portion of the Maximum Potential Drain Down Which Actually Spilled (Percent)

The results of this analysis are presented in Table 6-5D. As indicated, 75% of all leaks resulted in spill volumes which comprised only 4.5% or less of the maximum potential spill volume between the nearest adjacent block valves. The actual values corresponding to some of the other points along this curve are given below:

- 25% of the spill volumes represented less than 0.14% of the maximum potential drain down volume between adjacent block valves.

- 50% of the spill volumes represented less than 0.75% of the maximum potential drain down volume between adjacent block valves.

- 75% of the spill volumes represented less than 4.6% of the maximum potential drain down volume between adjacent block valves.

Table 6–5C
Spill Size Distribution
For Leaks With Adjacent Valve Spacing Distances

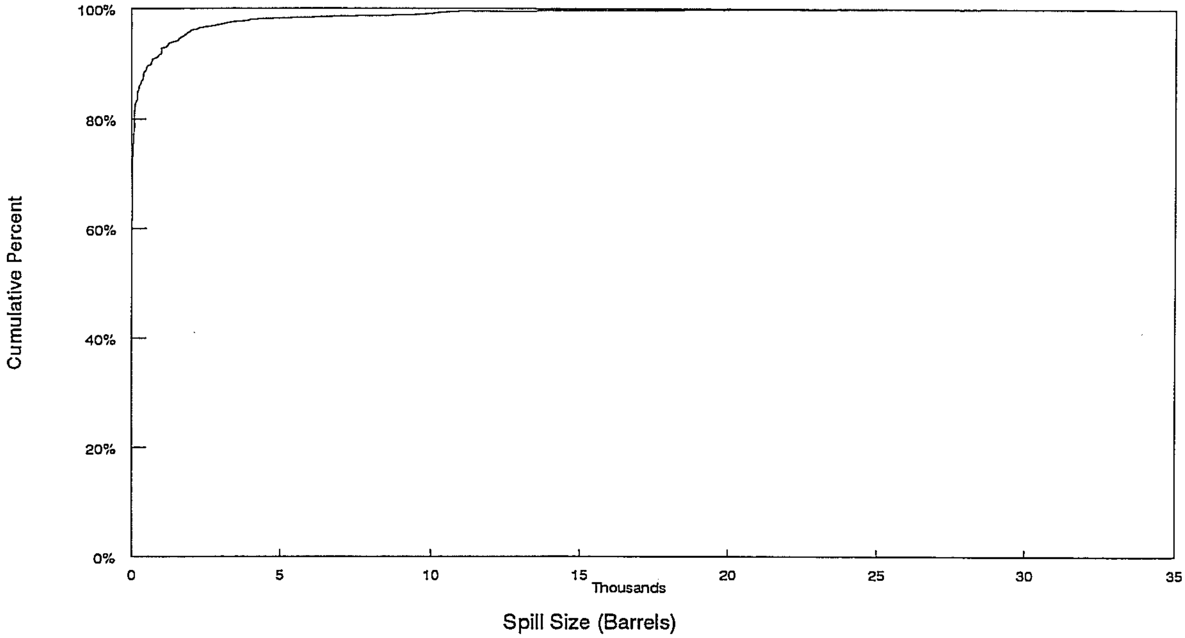
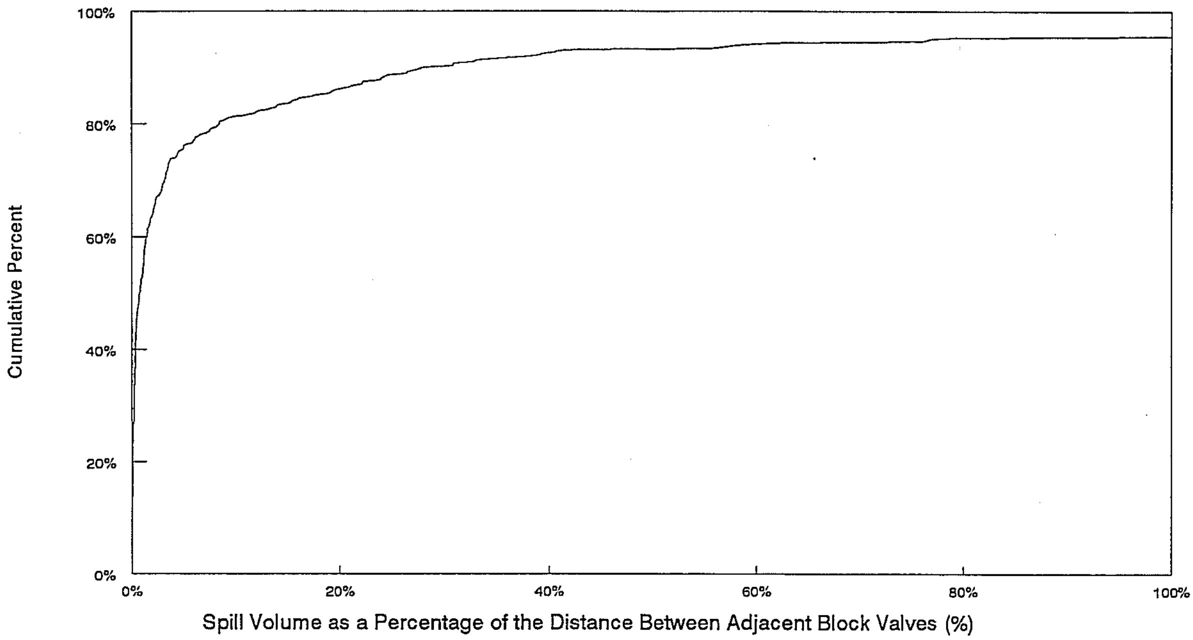


Table 6–5D
Distribution of Spill Volumes
As A Percentage of The Distance Between Adjacent Block Valves
(For Leaks With Adjacent Valve Spacing Distances)



- 80% of the spill volumes represented less than 8.5% of the maximum potential drain down volume between adjacent block valves.

- 90% of the spill volumes represented less than 28% of the maximum potential drain down volume between adjacent block valves.

- Only 6.4% of the total number of incidents resulted in spill volumes which were greater than 50% of the maximum potential drain down volume between adjacent block valves.

- Only 4.6% of the total number of incidents resulted in spill volumes which were greater than the maximum potential drain down volume between adjacent block valves.

The actual effect of each spill volume component (e.g. continued pumping, drain down, etc.) was impossible to evaluate with the data available. As a result, the values presented above represent the effects of *all* spill volume components.

For example, for 50% of the leaks, the actual spill volume was less than 0.75% of the total volume between block valves. Considering spill volume components which are not affected by block valves (e.g. continued pumping), the actual spill volume which could have been affected by closer block valve spacing would have been somewhat less than 0.75%. These results indicate that other factors (e.g. natural terrain) considerably reduced the spill volumes associated with leaks on California's regulated hazardous liquid pipelines. From this data, one could conclude that the number of block valves would have to be increased by at least 100 times, in order for block valve effectiveness to begin to approach a direct relationship between block valve spacing and resulting spill volumes for the majority of pipeline leaks.

Looking at this another way, *neglecting all other spill volume components*, reduced block valve spacing could have *directly* affected spill volumes on a maximum of only 4.6% of the incidents.

The spill sizes versus the maximum potential drain down lengths (L_{Drain}) are plotted in Table 6-5E. As shown, the vast majority of this data indicates relatively small spill volumes, regardless of the distance between adjacent block valves. However, a few very large volume spills are scattered among the data.

A line was fitted to this data using the least squares method. Although the line resulted in a slightly increasing trend, 46 barrels per additional mile between adjacent block valves, the resulting *R squared* was a very low 0.027.

The data presented in Table 6-5E does not consider pipe diameter variations. Since the spill volume from a given length of potential drain down is related to the square of the pipe diameter for a given size spill, the results contain some inherent error. As a result, a separate analysis was performed after normalizing the data to correspond with 12.750" outside diameter, 0.250" wall thickness pipe. (These values are very close to the mean pipe diameter and wall thickness values for all pipe included in the study.) The data was normalized by multiplying the actual spill volumes by the ratio of the actual leak pipe cross sectional area divided by the cross sectional area of 12.750" outside diameter, 0.250" wall thickness pipe.

The resulting *normalized* spill volumes versus the maximum potential drain down lengths are shown on Table 6-5F. As before, the vast majority of these data showed very small spill volumes, regardless of the distance between adjacent block valves. However, a few very large volume spills were scattered among the data.

A line was fitted to this data using the least squares method. The line resulted in a slightly increasing trend, 31 barrels per mile; however, once again the resulting *R squared* was a very low 0.017.

In other words, after normalizing the data, although not statistically relevant, reduced block valve spacing would result in a 31 barrel spill volume reduction per mile of block valve spacing reduction. Taking this one step further, if the number of block valves were doubled on California's regulated pipeline systems by adding 1,909 valves, the average block valve spacing would be reduced from 3.12 miles to 1.76 miles. This would result in only a 13% reduction in overall spill volumes, from 325 to 283 barrels. The overall reduction in damage would likely be much less than 13%.

6.6 Cost Benefit Analysis

Although there is little statistical correlation between block valve spacing and the resulting spill size, a simple cost benefit analysis will be presented in this section for completeness. The reader is cautioned against using this information for anything more than a benchmark; the very low statistical relationship between block valve spacing and spill size provides little merit to the results. Further, it is possible that additional valves may increase the likelihood of leaks occurring; the data presented in this section does not include any correction for leaks which may result from additional valves.

The *normalized* values presented by the least squares line of best fit shown in Table 6-5F will be used to estimate the benefits associated with additional block valves. As stated earlier, this line of best fit has a slope of 31 barrels per mile of block valve spacing reduction. For our average block valve spacing of 3.12 miles, the line of best fit indicates a 325 barrel spill size.

Table 6–5E
Spill Size Versus Drain Down Length
Raw Data – Unadjusted For Pipe Diameter Variations

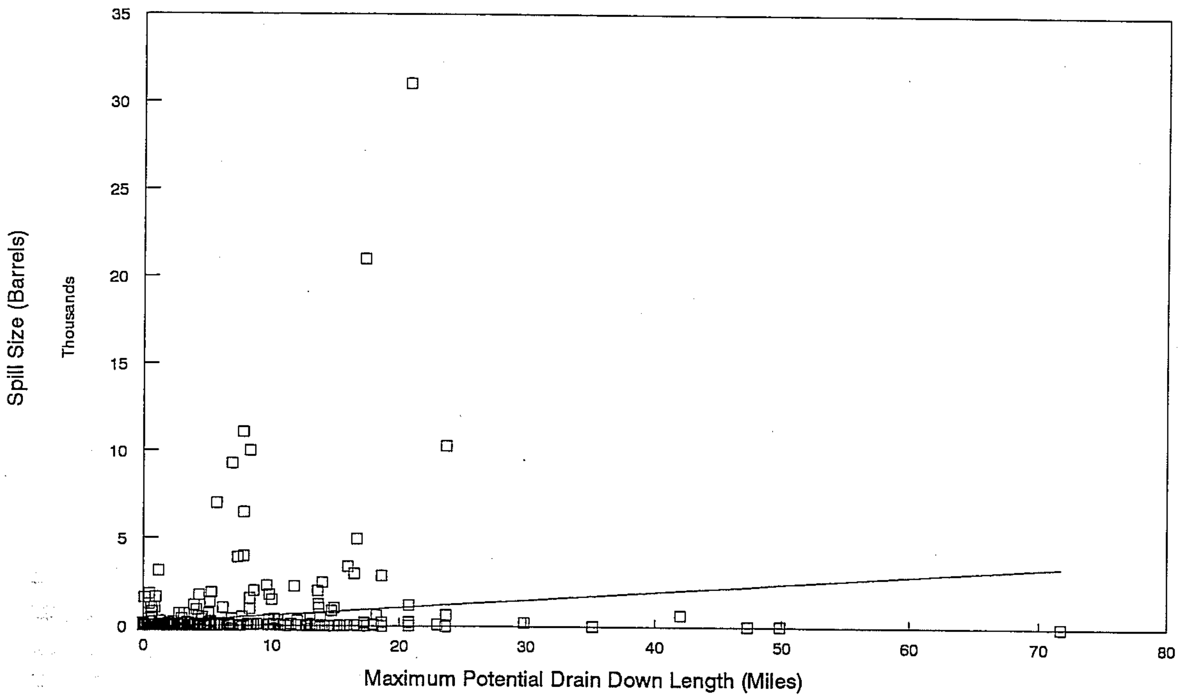
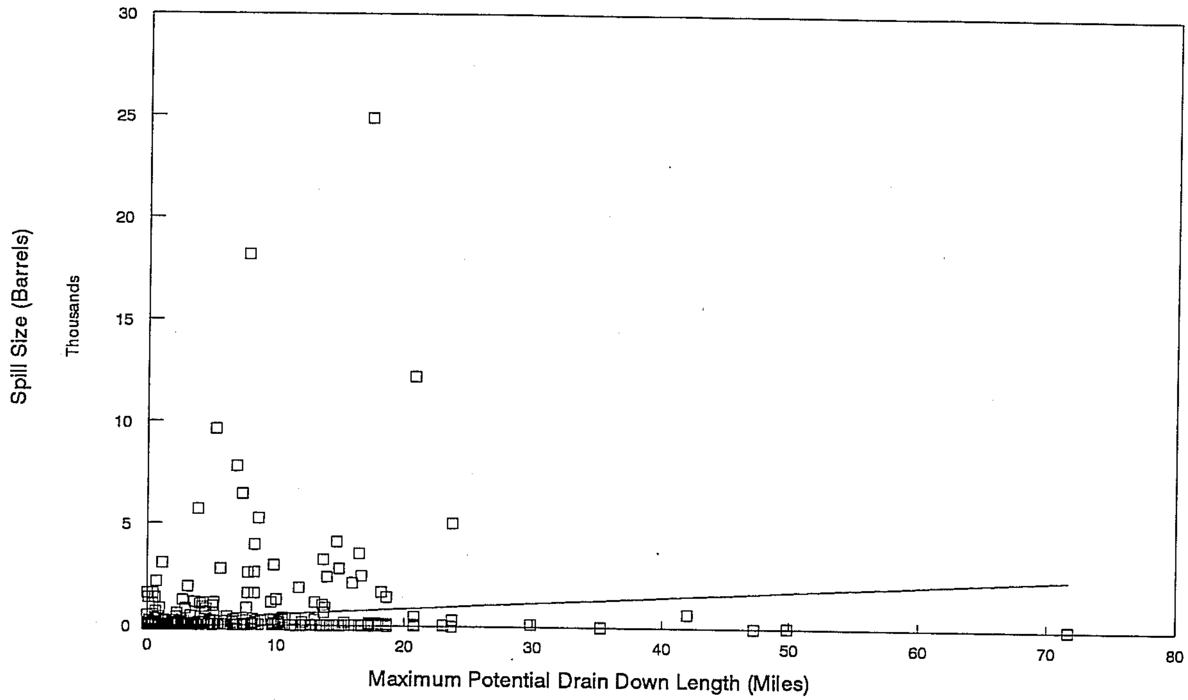
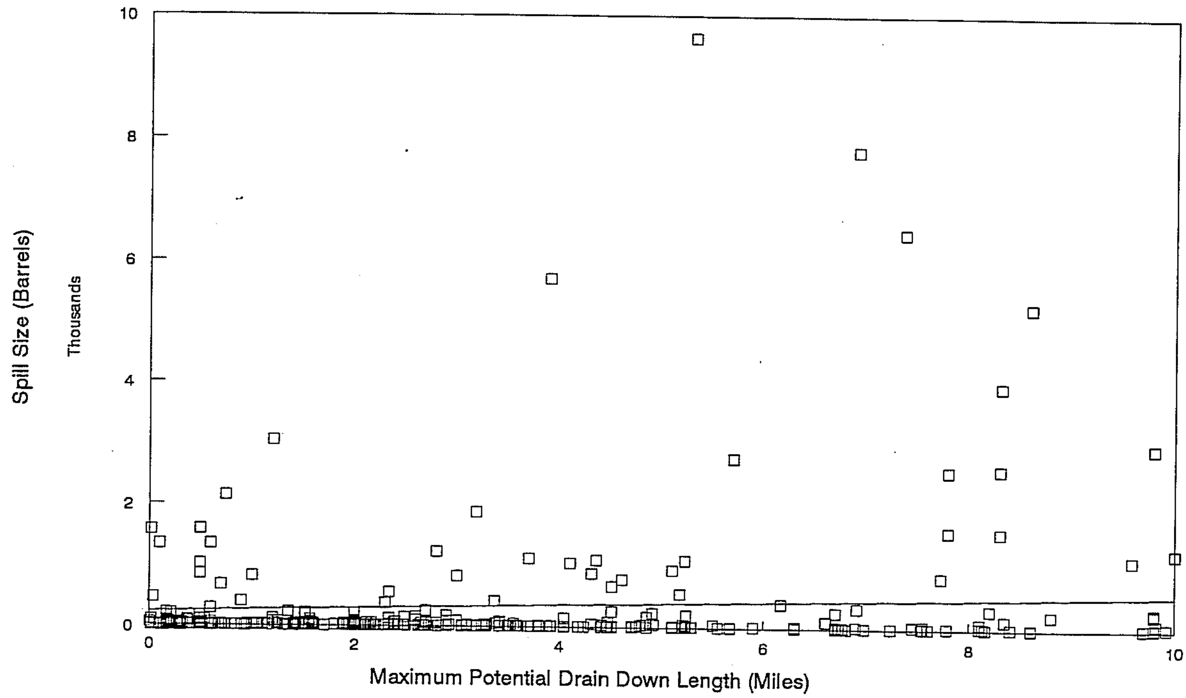


Table 6–5F
Spill Size Versus Drain Down Length
Adjusted Data – Normalized For 12.75" O.D., 0.25" W.T.



Spill Size Versus Drain Down Length
Adjusted Data – Limited Range



The approximate unit costs associated with adding additional block valves, as used in the analyses, are itemized below:

· Cost per additional block valve installation	$25,000/Valve
· Additional Block Valve Maintenance	$500.00/Valve/Year
· Useful Line	20 Years

For the purposes of these analyses, we assumed that the cost of maintenance would increase at the same rate as inflation.

The approximate benefits used in the analyses are shown below:

· Average Damage	$141,000/Leak
· Rate of Damage Increase	$23,000 Per Year
· Inflation	7%/Year
· Average Spill Size	408 Barrels (bbl)
· Average Cost Per Barrel Spilled	$346/Barrel
· Spill Volume Reduction	31 bbl/Mile Valve Spacing Reduction
· Probability of Leak	7.3 Incidents/1,000 Mile Years

In evaluating the potential benefits associated with additional block valves, there was one significant unknown, the relative value of minimizing additional fluid being spilled. Specifically, block valves do not prevent leaks; they are only effective in minimizing a portion of the spill volumes associated with them. We believe that the costs associated with the last barrels spilled are far less than the first few barrels spilled.

For example, consider our average 408 barrel spill. If additional block valves were added to reduce the average spill volume 25%, to say 306 barrels, we would not expect the average damage to be reduced by a corresponding 25%. We would expect the average damage value to be reduced little, if any, by this action. However, we do not have data available to quantify this position.

As a result, in the two scenarios which follow, the cost benefit analyses were performed assuming various values for this unknown. Cost benefit ratios were determined assuming 10%, 25% and 50% values for this unknown. We believe that the actual value was likely between 10% and 25%. In other words, if the average spill volume could be reduced say 25%, the value of the reduced spill volume would be between 10% and 25% of the value calculated using average damage per barrel spilled figures; this would result in an overall damage reduction of between 2.5% and 6% (10% of 25% and 25% of 25% respectively).

For the first scenario, we examined the relative benefits associated with adding various numbers of valves to California's regulated hazardous liquid pipelines. The analyses considered adding between 250 to 1,909 valves to the existing pipeline systems. Adding these valves would result in an average valve spacing reduction from 3.12 miles, to between 2.83 miles and 1.76 miles respectively (depending on the actual number of additional valves). The results are shown graphically in Table 6-6A. The raw data, using a 10% effectiveness factor, is shown below.

	250 Valves	500 Valves	1,000 Valves	1,909 Valves
Estimated Cost (Present Value)	$8,750,000	$17,500,000	$35,000,000	$66,815,000
Estimated Benefit (Present Value)	$402,000	$737,000	$1,261,000	$1,907,000
Cost Benefit Ratio	21.8 : 1	23.7 : 1	27.7 : 1	35.0 : 1

As stated earlier, by doubling the number of block valves on California's regulated pipeline systems from 1,909 to 3,818, the line of best fit indicates that the average spill volume would only be reduced 13%, from 326 to 283 barrels. The resulting damage would be reduced by between 1.3% and 3%, in our judgement.

The second scenario considered six 12" pipeline segments ranging from one to ten miles. Separate analyses were made for each segment, assuming the addition of one intermediate block valve at the middle of each segment. The results are depicted graphically in Table 6-6B. The cost benefit ratios for the various effectiveness factors and segment lengths considered are shown below.

Pipe Segment Length	10% Factor	25% Factor	50% Factor
1 Mile	384 : 1	153 : 1	76.8 : 1
2 Miles	96.0 : 1	38.4 : 1	19.2 : 1
3 Miles	42.7 : 1	17.1 : 1	8.54 : 1
4 Miles	24.0 : 1	9.60 : 1	4.80 : 1
5 Miles	15.4 : 1	6.15 : 1	3.07 : 1
10 Miles	3.84 : 1	1.54 : 1	0.77 : 1

Table 6–6A
Cost Benefit Ratios
Additional Block Valves On All California Regulated Pipelines

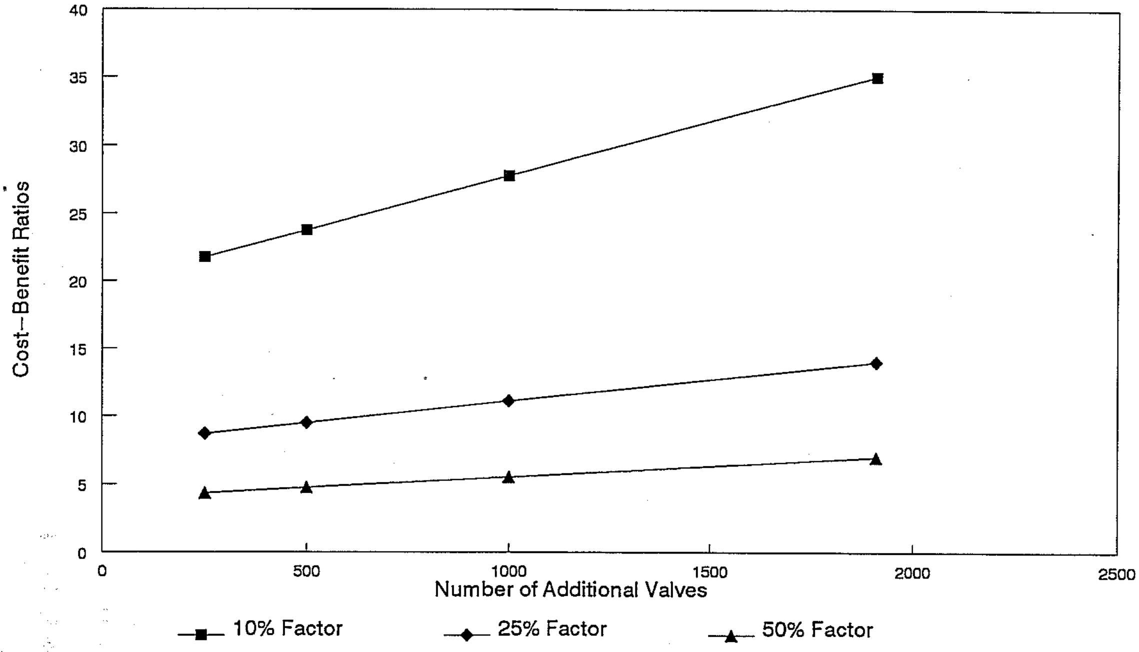
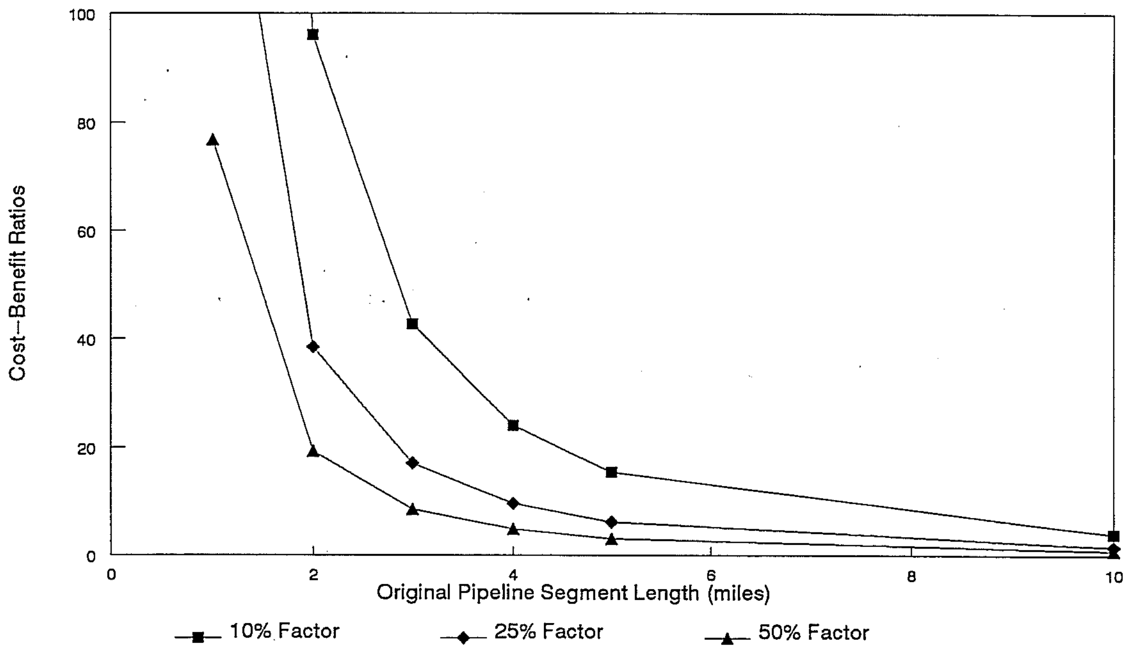


Table 6–6B
Cost Benefit Ratios
Additional Block Valves On Individual Line Segments



This data indicates that there may be some justification for additional block valves on very long segments of pipeline. However, since natural terrain and other factors affect each situation differently, each case would require individual investigation.

For completeness, it should be noted that some have argued that cost benefit analyses are not appropriate for analyzing the effects of various aspects of pipeline regulations. While not necessarily the authors' opinion, this view was summarized in the National Transportation Safety Board's Special Study of Effects of Delay in Shutting Down Failed Pipeline Systems and Methods of Providing Rapid Shutdown - Report Number NTSB-PSS-81-1, December 30, 1970, which stated,

> "The degree of security to be provided by pipeline regulations has sometimes been assessed by applying cost-benefit criteria. How much larger is the amount of loss to be prevented than the cost necessary to prevent this loss? This criteria is applicable to a situation when the benefits in reduced risk and the costs are shared within the same group. However, the risks and losses from pipeline accident exposure and the costs of hazard reduction are not within the same group.
>
> Those at risk from pipeline accidents are sometimes employees of the system; more often they are members of the general population who happen to live near a pipeline, or to be near it by chance. These people may not benefit from a given type of pipeline transportation, even indirectly. At most, they benefit from the service only to the same degree as others in the population. These people do, however, carry the risk for the benefit of the rest of society. The benefitting groups in society are the natural gas or liquid fuel users and the profit making institutions which operate the lines. One way to equalize this risk would be to reduce it to zero, so that those near the pipeline have the same risk as those who benefit from the pipeline service. Alternately, since it is not possible to reduce a risk to zero, funds could be employed to reduce the risk to a point well below what would be justifiable by requiring the benefits to match or exceed the costs. Those who are bearing the risk deserve to be protected by expenditures far beyond the dictates of cost benefit."

6.7 Cost Benefit Analysis - HVL Lines

In January 1978, a Notice of Proposed Rulemaking was issued regarding pipelines carrying highly volatile liquids (U.S. Department of Transportation, Docket Number PS-53). This rule proposed that valves be located no more than 7 1/2 miles apart when relocating, replacing, or otherwise changing existing steel highly volatile liquid (e.g. propane, ethane, butanes, and anhydrous ammonia) pipeline systems in inhabited areas. The proposal resulted from the Department's findings that highly volatile liquid pipeline accidents generally caused more damage to life and property than non-highly volatile liquid pipeline accidents. The proposed rule stated in part, "Each sectionalizing valve on a pipeline in an inhabited area that transports highly volatile liquid must be either equipped for operation at an attended location or designed to operate automatically unless it is located 3.7 miles or less from a sectionalizing valve that is so equipped or designed."

The American Petroleum Institute published A Cost benefit Analysis of Proposed Safety Regulation of Valve Spacing and Operation in May 1979. It presented the results of questionnaires from 61 pipeline systems, 218 highly volatile liquid pipeline accidents, and public information. The cost and benefit impacts were presented for existing lines only; they did not include an analysis of newly constructed lines. Briefly, the study found:

- The cost to benefit ratio was at least 40:1. As a result, the study found that, "...when the relation of total benefits to total costs for society as a whole is considered as a criteria in judging the desirability of regulation, the proposed regulation is ineffective and wasteful." In addition to property damage, values of $1,000,000 for life and $250,000 per injury were used in the analyses ($U.S. 1979).

- The average cost to add new valves was $48,850 per valve. (Converting to $U.S. 1983, to be consistent with other data presented in this report, yields an average of $67,286.)

- The average cost to convert existing valves was $30,700. (Converting to $U.S. 1983, to be consistent with other data presented in this report, yields an average of $42,286.)

- The study stated that additional remotely actuated or automatic valves would cause additional accidents since the valves themselves could leak or malfunction. Further, the valves could be closed unintentionally, as a result of a malfunctioning automatic or remote closing apparatus, causing other operational problems.

- 86 accidents occurred on sections in inhabited areas which were bracketed by block valves less than 7.5 miles apart. These incidents accounted for 84% of the deaths, 48% of the injuries, and 39% of the property damage among all incidents. The study suggests that this indicates that closer valve spacing contributes little or nothing to hazard reduction.

6.8 Emergency Flow Restricting Devices

In March 1991, the U. S. Department of Transportation published a study entitled, Emergency Flow Restricting Devices Study, regarding emergency flow restricting devices. This study was intended to fulfill the requirements of Section 305 of the Pipeline Safety Reauthorization Act of 1988. For this study, only remotely controlled block valves (RCV) and check valves were considered emergency flow restricting devices. Since pipeline safety could be adversely affected by the installation of automatic control valves, they were not included in the study. The study findings are outlined below:

- The study considered five scenarios. The analyses considered four criteria: safety, cost, feasibility and effectiveness. However, complete cost data was only available for one of the scenarios, hazardous liquid pipelines in urban areas.

- Although data was not available to perform a cost benefit analysis, the study concluded that requiring the retrofitting of all existing manually operated valves to RCV's on hazardous liquid pipelines in rural locations was probably not justified due to the high cost involved. (The study assumed a cost of $40,000 per valve to convert from manual to remote actuation.)

- For hazardous liquid pipelines in urban areas, the study *assumed* that installing RCV's, in lieu of manually operated valves, would result in a 75% reduction in all safety and environmental accident effects. (This assumption was not substantiated.) Using this assumption, the analysis concluded that converting existing manually operated block valves to RCV's would have a 1:1.59 cost benefit ratio. Adding additional RCV's resulted in a 1:1.24 cost benefit ratio. However, the study noted that RCV's would only be effective on systems with effective SCADA systems with leak detection sub-systems.

- Underwater RCV's as emergency flow restricting devices on offshore pipelines were not recommended because of their unreliable operation.

- The study concluded that past pipeline operating experience obviated the need for a demonstration project.

In July 1987, the American Petroleum Institute published a report which included a section on this topic. Regarding the costs and benefits associated with converting existing block valves to automatic or remote operation, the study, entitled The Safety of Interstate Liquid Pipelines: An Evaluation of Present Levels and Proposals for Change, found:

- The capital cost to equip the 7,018 manually operated valves which are not used for facility isolation for remote actuation would be $299 million, or an average of $42,000 per valve. Operating costs for these valves would be an additional $17 million per year, or $2,400 per valve per year.

- The capital cost to equip the locally operated valves used for station isolation for remote actuation would be $406 million, plus an additional $22 million annual year operating cost.

- By reviewing detailed information available for 336 accidents, the study found that only 55% of the accidents could have potentially benefitted from remote or automatic valve operation. These 187 accidents resulted in 31% of the fatalities, 26% of the injuries, and 37% of the property damage. Using this data, one could conclude that the actual effect of converting manually operated valves to remote operation would result in benefits which would be some fraction of these percentages of the total fatality, injury and property damage figures.

  Extrapolating this data to cover all pipeline incidents, the study found that the maximum potential benefit would be $7 million per year, at an annual cost of $109 million. The resulting cost benefit ratio was 15:1.

A third study, Rapid Shutdown of Failed Pipeline Systems and Limiting of Pressure to Prevent Pipeline Failure Due To Overpressure, was prepared by Mechanics Research, Inc. for the Department of Transportation in October 1974. This study also addressed the effectiveness of remotely controlled block valves on hazardous liquid pipelines. This study found,

- Adding leak detection and remotely operated valves to existing pipelines in populated areas would result in a 18:1 cost benefit ratio using a 20 year useful life.

- Adding leak detection and remotely operated valves to all new pipelines constructed in populated areas would result in a 56:1 cost benefit ratio using a 20 year useful life.